REGARDING THE RATE OF GROWTH OF THE AMERICAN LOBSTER.[1]

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At the present time when artificial propagation is bidding fair to at least partially check the ever-increasing depletion of many forms of marine animals whose economic value has long sustained a many-sided fishing industry, any facts which may bear directly or indirectly upon the life, habits or development of such forms might seem to be of value. This is especially true of the American lobster (*Homarus americanus*), a knowledge of whose development must influence not only methods of artificial propagation, which is in these days becoming more common, but also state legislation in determining the size and season at which the taking of lobsters shall be allowable.

The Frequency of Molting and the Percentage of Increase.

The rate of growth of a lobster depends primarily upon two factors, the frequency of the molting periods and the amount of increase in length at each molt. To date, the most complete and only satisfactory account of the development of *Homarus* is presented by Herrick[2] who made many observations at Woods Hole on all of the earlier and many of the later stages. Herrick found that young lobsters (stages 2 to 10) in confinement gain from 11 to 15.84 per cent. at each molt, the average in 66 individuals being 13.5 per cent. He assumes that 15.3 per cent. is the average rate of increase both for the young lobsters which grow up in natural environments, and for adults under normal con-

[1] This paper is presented with the purpose of giving in brief the main facts of a more detailed report on this subject to the Rhode Island Fish Commission. The full account will appear in *The Thirty-Sixth Annual Report of the Rhode Island Commission of Inland Fisheries, 1906.* Reprinted as *Special Paper No. 23, 1906.*

[2] Herrick, *U. S. F. C. Bulletin*, vol. 15, 1895.

ditions. The difference in the above percentages he attributes to the unfavorable conditions of aquarium life. Taking this fact as a basis, and assuming the average length of the first stage lobster to be 7.84 mm., Herrick then constructs the following scheme to show the probable relation between the stage and the size of lobsters from the time of hatching through the thirtieth molt:

Stage.	Length.	Stage.	Length.	Stage.	Length.
1	7.84	11	32.55	21	135.17
2	9.04	12	37.54	22	155.86
3	10.42	13	43.28	23	179.70
4	12.02	14	49.90	24	207.20
5	13.86	15	57.53	25	238.90[1]
6	15.98	16	66.34	26	275.45[2]
7	18.42	17	76.49	27	317.59
8	21.24	18	88.19	28	366.16
9	24.49	19	101.68	29	422.21
10	28.23	20	117.24	30	486.81[3]

[1] 9.5 inches. [2] inches. [3] 19.1 inches.

Regarding the probable *frequency* of molts, Herrick assumes that a lobster molts fourteen to seventeen times during its first year of life, and that in this time it attains a length of two to three inches. From this and other detailed considerations, Herrick finally concludes that a lobster ten and one-half inches long is between four and one-half and five years old, the higher degree of probability being in favor of the lower estimate.

The observations made by the writer and others at the experiment station of the Rhode Island Fish Commission at Wickford, R. I., though differing to some extent from the results obtained by Herrick at Woods Hole, may serve to throw further light on the rate of growth of lobsters in their natural environment, and give some hint as to the conditions which modify it.

The record of the rate of growth of the early stages (one to ten) include observations upon several hundred young lobsters whose definite stage and approximate age was, for the most part, known. Individual records were started immediately after the molt from the third to the fourth stage and were carried on as long as either the weather conditions or the term of life of the young lobsters permitted. In most cases the young individuals were confined in separate compartment cars which furnished a

very natural environment, and rendered it easy to make observations at any time. The facts concerning the development of the early stages may be more tangible when presented in the following table :

WICKFORD LOBSTERS.

Stage.	Length.	Stage-period.	Per cent. Increase.
1	8.2 mm.	2 days	
2	9.6	4 days	17.0
3	11.4	5 days	19.2
4	13.5	12[1] days	18.6
5	16.0	11[1] days	15.0
6	18.8	12.5 days	19.9
7	22 5	14 days	21.0
8	26.5	15.5 days	17.0
9	32.0	21 days	21.0
10	37.9	25 days	17.0
			Total average 18.3

WOODS HOLE LOBSTERS.

Stage.	Length.	Stage-period.	Per cent. Increase.
1	7.84 mm.	1– 5 days	
2	9.20	2– 5 days	17.3
3	11.10	2– 8 days	20.6
4	12.60	10–19 days	13.3
5	14.20	11–18 days	12.7
6	16.10	14 days	13.3
7	18.60		15.5
8	21.03		12.5
9	24.50		16.5
10	28.03		14.0
			Total average 15.3[2]

[1] The fifth stage-period is often shorter than the fourth because the water at Wickford is usually the warmest during the fifth stage-period.

[2] This percentage is greater than in the case of another group of 66 lobsters in which Herrick obtained a result of 13.67 per cent.

The foregoing demonstrates the fact that the average stage-period of the Wickford lobsters is less than the stage-period of the Woods Hole lobsters. Further that, while the percentage of increase at each molt for the Woods Hole lobsters (kept in aquaria) was only 13.5 or 15.3, the amount of increase for the Wickford lobsters was over 18 per cent. in the individuals recorded above, while in the case of a group of individuals which had been especially selected (*i. e.*, the smaller and weaker specimens were

thrown out) the average amount of increase for the first ten stages was 20.9 per cent. In this last instance the lobsters in the respective stages were consequently much larger than those in the group of Wickford lobsters tabulated above. Their average measurements, however, are presented in the following table:

Stage.	4	5	6	7	8	9	10
Length (mm.).	14.4	17.0	20.5	24.6	31.3	37.0	45.0
Stg.-per. (days).	11.7	11.2	12.2	13.5	15.1	21.0	25.1
Per cent. increase.		18.0	20.6	20.0	27.2	18.5	21.6

These and other observations would demonstrate that there are great variations in the rate of development of lobsters, not only in different localities, and under different conditions of environment, but also in the same locality and under identical conditions. Furthermore, that there is a tendency manifested in those individuals which are slightly above the normal in size and strength, to increase the advantage which they have already gained. This advantage, lodged in the fourth stage lobster, may be no more than a millimeter, but this slight gain compounded through numerous successive stages gives, even the tenth and eleventh stage, a decided lead which is never again lost and which may be observed in the last mentioned group.

Continued observations upon the later stages (from the tenth on) prove that not twelve to seventeen stages, as calculated by Herrick, but an average of twelve stages are passed during the first year of the lobster's existence. We may trace the future development of the young lobster through the later successive stages as follows: September finds the average individual, hatched the previous June, in the ninth stage and with an average length of 32 mm. He passes into the tenth stage in the latter part of September, with a corresponding length of 37.9 mm. In the latter part of October or the first of November he enters the eleventh stage with an increase to 45 mm. Through the months of November, December, January, February and March he lies dormant, passing into the twelfth stage some time in April or the first part of May. Thus it appears that a lobster one year old is in the twelfth stage and has an average length of 53 mm. There are always exceptions to this rule, — instances where an individual

may occasionally pass into the twelfth stage before the winter months. Such specimens sometimes manifest an increase of 28 per cent. in passing a single stage. These lobsters are, however, usually among those which were hatched early in the season, and are not very common.

From observations upon the yearling lobsters it becomes apparent that the young creature molts on the average of four times during its second year of life. The thirteenth stage is entered some time in July or August, with a corresponding length of 62 mm. In the latter part of August he molts for the thirteenth time and now covers 73 mm. The entrance to the fifteenth stage occurs in October of the second year. No further change takes place until the following April; that is to say that the average lobster passes its second winter in the fifteenth stage, length 86 mm. (3⅜ inches). By the middle of June we find the young lobster, now approximately two years old, in the sixteenth stage, and with a length of 102 mm. ($4\frac{1}{12}$ inches).

Observations on the molting periods of lobsters over two years old make it apparent that the entrance to the seventeenth stage takes place some time in the late summer of the third year. The lobster generally molts again before the winter months of the same year into the eighteenth stage with a length of 141 mm. (5⅝ inches). No further change is experienced until the following April.

After the seventeenth or eighteenth stage the percentage of increase at each successive molt undergoes a gradual diminution as the molting periods become less frequent. The amount of increase for lobsters about 6 inches in length appears to be in the neighborhood of 15 per cent. Thus continuing, we find that the young lobster passes its third winter in the eighteenth stage, molts again in the spring (usually in April) and by June, when approximately three years old, has a length of 162 mm. (6½ inches).

In lobsters of 7 inches and over we find a still smaller percentage of increase at each molt; 11 or 12 per cent. represents with a fair degree of accuracy the average percentage of increase in length for lobsters between 7 and 10 inches.

Further observation reveals the fact that lobsters over 6 inches

in length do not molt oftener than twice in a year; once in the spring or early summer and once in the autumn. Thus the average lobster enters the twentieth stage some time in the autumn of his fourth year and at this molt increases from 162 mm. to 181 mm. (7¼ inches). In the late spring or early summer of the following year the lobster, now approximately four years old, enters the twenty-first stage with a corresponding length of 200 mm. (8 inches).

If the case is not one of a young female bearing external eggs (very rare in lobsters of this length), we may expect another molt the following autumn and consequently find the lobster in the twenty-second stage now with a length of 222 mm. (8⅞ inches). In all probability the molting periods of the male and female remain the same until past the nine-inch length. Therefore, the entrance to the twenty-third stage probably takes place just before, or at any rate soon after, the lobster becomes five years old. The corresponding length is 247 mm. (9⅞ inches).

By the time this length is reached many of the female lobsters are sexually mature and are bearing external eggs. Owing to this fact, from this time on the rate of growth of the females must be much diminished. This is due no doubt to the checking of the growing process, a phenomenon which very naturally precedes the spawning period; also to the length of time (ten to eleven months) the eggs are carried. The male lobsters, on the other hand, maintain their former rate of development so that by the twenty-fourth stage the average male lobster has a length of 275 mm. (11 inches) and cannot be much less than six years old. In the case of the females, however, which have borne eggs since the nine-inch stage, the eleven-inch limit cannot be attained in a shorter period than eight years.

This discrepancy in the rate of growth of the male and female lobsters from this time on, is undoubtedly the explanation of the fact that, in nearly all individuals in which the sex has been observed, the "giant" lobsters have been of the male variety. There are few data on the rate of growth of large lobsters but it is probable that after the ten-inch size has been attained, the lobster does not molt oftener than once in a year; and after the fifteen-inch stage not oftener than once in two years. Regarding

Stage No.	Sex.	Age.	Length, mm.
1	Male and		8.2
2	Female.	3 days.[1]	9.6
3	"	7 days.	11.4
4	"	12 days.	13.5
5	"	24 days.	16.0
6	"	36 days.	18.8
7	"	7 weeks.	22.5
8	"	9 weeks.	26.5
9	"	3 months.	32.0
10	"	5 months.	37.9
11	"	9 months.	45.0
12	"	1 year.	53.0
13	"	1 yr. 1 mo.	62.0
14	"	1 yr. 3 mo.	73.0
15	"	1 yr. 6 mo.	86.0
16	"	2 yrs.	102.0
17	"	2 yrs. 3 mo.	121.0
18	"	2 yrs. 6 mo.	141.0
19	"	3 yrs.	162.0
20	"	3 yrs. 6 mo.	180.0
21	"	4 yrs.	200.0
22	Male.	4 yrs. 6 mo.	222.0
"	Female.	4 yrs. 6 mo.	"
23	Male.	5 yrs.	247.0
"	Female.	6 yrs. 5 mo.[2]	"
24	Male.	6 yrs.	275.0[3]
"	Female.	8 yrs. 4 mo.	"
25	Male.	7 yrs.	300.0
"	Female.	10 yrs. 4 mo.	"
26	Male.	8 yrs.	327.0
"	Female.	12 yrs. 4 mo.	"
27	Male.	9 yrs.	356.0
"	Female.	14 yrs. 4 mo.	"
28	Male.	10 yrs.	380.0
"	Female.	16 yrs. 4 mo.	"
29	Male.	12 yrs.	406.0
"	Female.	18 yrs. 4 mo.	"
30	Male.	14 yrs.	431.0
"	Female.	20 yrs. 4 mo.	"
31	Male.	17 yrs.	457.0
32	"	20 yrs.	480.0
33	"	23 yrs.	505.0
34	"	26 yrs.	525.0
35	"	29 yrs.	546.0
36	"	33 yrs.	568.0[4]

[1] Age at entrance to the stage.

[2] Assumes that the lobster spawns for the first time in the summer of its sixth year, and that the eggs hatch the following summer.

[3] 11 inches. [4] 22¾ inches.

the growth of "giant" lobsters, it appears reasonable to believe that the molting process does not occur oftener than once in three years; and this is a small estimate. The amount of increase in these specimens at a single molt cannot be over four or

five per cent. and is often inappreciable. The shells of these huge lobsters present every appearance of great age and give testimony to a life of inactivity. Using as a basis the observations which led to the foregoing conclusions, the writer has compiled a table showing the estimated rate of development of lobsters from the time of hatching to the attainment of the greatest known size. While the data on the first twenty stages have their ground in actual observation, the records of the later stages have been deduced from less positive evidence, and are, to a great extent, speculative. The great variation in the size of lobsters, even of the same age and stage, render it well-nigh impossible to tell off-hand the age of any adult lobster. On the other hand, the size of large numbers of individual lobsters of a certain age must remain not far from a general average, on a basis of which, the approximate age of large numbers of individuals can be determined with a fair degree of certainty. It is this average, together with the correlated age, that the writer has attempted to formulate in the preceding table:

Influences on the Rate of Growth.

Among the influences which modify the rate of growth of young lobsters under natural or artificial conditions, are to be mentioned especially the following: temperature, food supply, light, parasites, injuries and individual physiological peculiarities. It is probable that the water temperature and physiological condition are the most influential for young lobsters in the ocean. The others enter largely into consideration in the problems of artificial propagation. The frequency of the molting periods and, secondarily, the amount of increase in length at each molt, is directly dependent upon and determined by the prevailing temperature of the water; a difference of twelve degrees may cause the period of growth to the fourth stage to be over twice as long as normally. Thus we find great variations in the rates of growth of lobsters at different points on the Atlantic coast. For this reason it is very probable that the lobsters in the warm waters of Narrangansett Bay may attain marketable size (10½ inches in Massachusetts) much sooner than do the Massachusetts or Maine lobsters.

It is apparent through other observations that the effects of strong lights and, as shown by Emmel,[1] the mutilation of appendages, exert an influence detrimental to the development of the lobster in the early stages. Excessive sunlight in cases where the lobsters were exposed superficially in the water, appears to cause not only a marked increase in the duration of the stage-periods, but also a diminution in the percentage of increase in length at molts; and furthermore, a generally less healthy condition in the lobsters themselves. This may be brought about either directly, by inhibiting the body processes and general metabolism, or indirectly, by favoring the excessive growth of diatoms, algæ and protozoa which, under certain conditions, may accumulate on the body and appendages, to such an extent as to prevent nearly all activity. It is also observable in this connection, that food supply may play an important rôle in determining the size of the young lobster.

[1] V. E. EMMEL; "The Regeneration of Lost Parts in the Lobster," *The Thirty-Fifth Annual Report of the Rhode Island Commission of Inland Fisheries, 1905.*